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CONTENTS:

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Histology of *Malva rotundifolia.*

GRACE McCRONE.

Plates LIV-LIX.

MALVA ROTUNDIFOLIA is a low-growing mallow common in this section of the country, and generally growing as scattered individuals or small groups, but sometimes occurring in large patches. It begins growth early in spring and lasts until very late in autumn.

The material used for this investigation was obtained on the University campus. The standard histological methods were employed, and the illustrations were made from permanent slides stained with safranin and hæmatoxylin and from free-hand sections otherwise treated. Microchemical tests were used on both free-hand and microtome sections. Some of the drawings were made by use of the camera lucida on the microscope and some with the projectoscope.

STEM.

The main stem branches perfusely close to the ground. The branches start up in a vertical direction, but as they become numerous the older branches lie prostrate on the ground for a greater part of their length. This position has a noticeable effect on the tissues of the stem, there being less bast fiber tissue on the lower than on the upper side, and in the starch sheath there is more starch in the side near the ground. The branches are about two or two and one-half feet long.

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The epidermis of the stem is closely covered with hairs, which are of the same general type as those of the leaf (figs. 4 and 8). The hairs are mostly stellate, with from five to nine rays. Each ray is a single cell, the center of which stains darker with safranin than the outside, giving the appearance of a core. There are also many simple unicellular hairs, similar in structure to one ray of the stellate hair, and many glandular hairs, knoblike in shape (fig. 8, *f*). These latter are frequent on the young parts of the stem and petiole and large veins of the leaf. The epidermal cells of the stem (fig. 7) are rather irregular in size and shape but have a general rectangular form. The stomata (fig. 7, *a*) vary more in shape than those of the leaf and are slightly larger. They stand with the long axis parallel with the long axis of the stem and are not so close together as those of the leaf.

Collenchyma is always present in young stems (figs. 25-26, *b* and 30-33, *a*) and in the petioles of the leaves (fig. 22, *c*), but in older parts of the stem it is thrown off when cork (figs. 34 and 35, *a*) is formed.

The vascular bundles are of the usual collateral type, and the bast fibers stand just outside of the phloëm strands, making a broken line around the outside of the phloëm (figs. 32, 33 and 38). The vascular bundles vary in size, and a large and a small one or two large ones and two or three small ones are often found alternating. The cross section of the very young stem is irregular in shape instead of being circular as in the older parts of the stem, and the large bundles are likely to be where the stem is prominent (fig. 30). In the older part the stem is nearly circular and there is less irregularity in the size of the bundles (figs. 30-35).

The changes in structure from the new to the older parts of the stem are shown in figures 30-35. The sections from which the illustrations were made were taken from the stem, first just below the growing point, second about two inches below, and at intervals all of the way down the stem to the root, representing six different regions of the stem. In the first four sections the pith covers the greater part of the diameter, but in sections nearer the base of the stem the pith becomes smaller and is nearly crowded out of existence.

The bast fibers are found in sections about three inches from the apex of the stem, a bundle of bast fibers standing before

each phloëm strand. As the stem grows older the original bast fiber bundles are pushed outward and apart, and new bast fibers are produced by the cambium, until in the older parts one finds groups of bast separated by phloëm tissue and extending in radial rows (figs. 34 and 35).

The starch of the stem is all found in the starch sheath. This in the young parts of the stem forms a continuous layer of cells composed of the innermost cells of the thin-walled parenchyma of the cortex. In the older parts the bast fibers appear just inside the starch sheath. Then as the bast fiber region is extended radially the starch sheath follows these radial extensions of the bast fibers. Figures 33, *b*, to 35, *b*, illustrate this.

Wood fibers (fig. 18) are also formed and the older parts of the stem become quite woody. As the xylem develops the pith becomes smaller, the water-conducting area becomes much greater, as may be seen by a comparison of figures 30 to 35, the tracheal tubes becomes somewhat larger and their frequency is greatly increased. Figures 34-35 and 41-42 show details of water-conducting tissue.

The number of vascular bundles varies greatly, ranging from fifteen to twenty-three.

Crystals of calcium oxalate (fig. 19) occur closely packed together, sometimes in groups of cells and in other instances in isolated cells, in the pith and in the parenchyma of the cortex and pericycle. The crystals may be found any place in the parenchyma, but are more common along the bast fiber region. These crystals are all compound, and are often almost large enough to fill the cells which hold them. Figure 17, *a*, shows the distribution of crystals in the parenchyma cells of an old part of the stem.

Mucilage is found in large quantities in the stem (fig. 15). In the parenchyma of the cortex the cells containing it break down to form long tubes or passages filed with mucilage. These cells (fig. 24, *a*) sometimes also break down in lateral directions, making the mucilage cavities much larger in lateral diameter than the ordinary parenchyma cells, but in other instances the mucilage-filled cells (fig. 25) are not so much larger than the other cells. As the cells enlarge, in the older parts of the stem, the mucilage cells do not grow accordingly, and even get considerably smaller (figs. 25 and 26, *a*) as the

other cell walls press against their walls. Figure 16 shows some of these cells cut obliquely, showing the great amount of mucilage in some places. In some instances these tubes measure more than one mm. in length. There are also many mucilage cells in the collenchyma, but they are not generally larger than the other cells (and therefore too small to show to the scale of figs. 27 and 28) and not many tubes are formed. The pith contains many long tubes filled with mucilage (figs. 15, 27 and 28) much the same as those in the parenchyma of the cortex.

The plant from which this study was begun was brought into the laboratory in June, and was in the second year of its growth. From observations made from this plant it was determined that there is relatively much more mucilage in the young part of the stem, that is, within two or three inches from the tip, than in the older parts. Actual counts and measurements showed this, but later, in October, more material was obtained and in this mucilage was not quite so evident in any part, and especially not near the tips of the branches.

The amount of mucilage is much less in sections near the root than near the apices of the branches, while the starch is more abundant near the root. The root contains only a trace of mucilage during the growing season, while it is well filled with starch at all times. In the autumn there is a slight increase of starch in the root and a great increase in the mucilage content (fig. 29).

Crystals of calcium oxalate are very numerous in the parts of material gathered in October, but that obtained in June showed no trace of crystals. In material collected in early spring, however, crystals were present.

The cells of the borders of the pith are relatively small and heavy-walled, while in the center of the pith the cells are much larger, the walls thinner and more regular in shape, being round or nearly hexagonal where they have pushed together and crowded out the air spaces. In the older parts mucilage is seldom found in the pith.

LEAF.

The orbicular leaves are borne on long, slender petioles and spread out almost horizontally, except in hot or dry weather when the edges curl up. They vary in size from an inch and one-half to two inches in diameter. The margin is indented to

form seven shallow lobes, and through the middle of each lobe runs one large vein from which all of the veins branch to form a more or less close network of small veins.

The leaf is dorsiventral, with palisade tissue on the upper side only. The palisade cells (figs. 8, *c*, 9, *c*, 10, *a*) are usually closely packed together, with rather large air chambers beneath the stomata (fig. 10, *c* and *d*, and figs. 5 and 6) which connect with the numerous air spaces between the cells of the spongy parenchyma.

The surfaces of the leaf, both upper and lower, are covered thickly with hairs of three different kinds. The most numerous of these are stellate hairs having from five to nine rays (fig. 4). There are more hairs to the square millimeter on the young leaf than on the fully developed one. The average number of hairs on the young leaf is 36 to the square millimeter. This is just after the leaf has unfolded. A gradual decrease in number was found in leaves of successive ages, fully developed leaves having 13 to the square millimeter. Beside the stellate hairs, along the veins and along the margin of the leaf, are numerous one-celled hairs about the same in structure as one ray of the stellate hair. The surface of the hair is smooth. The center stains darker than the wall, giving the appearance of a core. The cells from which these hairs arise form a slightly raised papilla, while the stellate hairs are on a considerably raised papilla. The third kind mentioned are glandular hairs (fig. 8, *f*). These are many-celled hairs and are generally found at the veins. They are the same in structure as those found on the petiole and young parts of the stem. The nucleus in the cells of these hairs is always clearly visible.

The cells of the epidermis are very irregular in size and shape and the walls are thin (fig. 13). Waterproofing is furnished by a thin cuticle merely. Many of the epidermal cells are mucilagenous (fig. 13, *e*). Whether this mucilage is a modification of the cell wall or not has been discussed by Kuntze (1891). He describes the mucilage of the epidermis, which is characteristic of the mallow family, as being a modification of the cell wall. He quotes Dumont as believing that in some species at least the mucilage has a schizogenous origin. It is certain that young cells are sometimes stratified. In older tissue the walls appear to entirely dissolve and leave the muci-

lage tube or pocket. Kuntze says that it is generally the inner wall of the epidermis that swells most in water. This is true of *Malva rotundifolia* to some extent, but it is not always the case. It is stated as a characteristic of *Malvaceæ* that the epidermis of the leaves strongly swell in water, in some species all of the cells and in others only certain cells, and these sometimes in the upper epidermis only. In *M. rotundifolia* the mucilage is only in certain cells of the epidermis, and there is much more in the upper than in the lower.

Stomata are found on both sides of the leaf (fig. 18) in about the same numbers. They are more numerous in the fully developed leaf than in the young leaf. The average number to the square millimeter of the fully developed leaf is about 494, and of the young leaf 370. The stomata are in the same plane with the other epidermal cells or but very slightly project (fig. 10, *c* and *d*). There are extensive air spaces beneath the stomata, and the spaces in the spongy parenchyma communicate freely with them. Chloroplasts seem to be less numerous in the palisade cells than in the spongy parenchyma.

The veins are embedded in the spongy parenchyma, and only the main veins reach out to the epidermis. All veins are surrounded by large very thin-walled border parenchyma (fig. 14) whose cells have their long axis parallel with the length of the veins. The veins end free in a group of tracheids (figs. 1, 2, 3 and 11, *h*). Near the margin where the large veins terminate these groups are very complex (fig. 1, *a*, and 3). In each lobe of the leaf the central rib gives off lateral veins almost at right angles, in fact all of the angles in the branches of veins approach nearly a right angle. The veins are well distributed, making a close network throughout, with the ultimate branches standing about .09 millimeter apart in the old or fully developed leaf, and .11 millimeter in the young leaf.

ROOT.

The root is a tap-root going down more than two feet into the ground. There are but few lateral roots and no large ones. The bark of the root is very thick, covering about two-thirds of the diameter. Cork is formed on the outside as on the lower parts of the stem. The root contains a great amount of food material stored in form of starch, sugar, mucilage and protein. During the growing season there is only a trace of mucilage in the root, and not as much starch and sugar as in

the winter season when all parenchyma cells are well filled with starch, and there are large cells and tubes of mucilage thickly scattered through the same tissue. There is also a quantity of sugar distributed through the tissues. Grape sugar is present in a considerable quantity in both the first and second year's growth. The bark is much thicker than on the stem, the cells in general are larger and the water tubes are much larger.

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